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A single source ionized cluster beam deposition system was purchased and installed as part of a thin film research facility.

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The 1983 DoD University Research Instrumentation Program Grant to ISU was for construction of the first phase of a major thin film research facility. Specifically, the grant was to provide funding for a single source ultrahigh vacuum (UHV) ionized cluster beam (ICB) deposition system which was to be coupled by a UHV transfer system to film diagnostics chambers and other deposition systems.

The overall long term plan for the thin film facility (TFF) is shown in Figure 1. The sputtering system was constructed previously as part of a research program on deposition of AlN thin films being supported by AFOSR. The electron energy loss spectrometer with LEED and UPS was constructed with partial support from DoE and ISU funds. The triple source ICB and the scanning Auger spectrometer were proposed for the 1984 University Research Instrumentation Program. The SIMS analysis chamber is proposed for the 1985 URIP.

A large room to house the TFF was provided at the Applied Sciences Center at ISU. The room was totally renovated with the addition of a laminar flow clean air system and a double door air lock. The floor, walls, and ceiling were sealed to minimize dust problems and new lighting was installed. A service chase was constructed down the center of the room below where the UHV transfer line would be constructed. This chase provides all the required power for operation of equipment, water cooling line, compressed gas for operation of the pneumatic gate valves, high purity gas line for backfilling chambers and an exhaust line for venting of the mechanical vacuum pumps used to back the turbomolecular pumps. Emergency power circuits were included for critical items in case of a general power failure. Figure 2 shows part of the service chase and the laminar flow bench where substrates will be loaded into the transfer line. In addition, each system is provided with a load lock for direct insertion of substrates.

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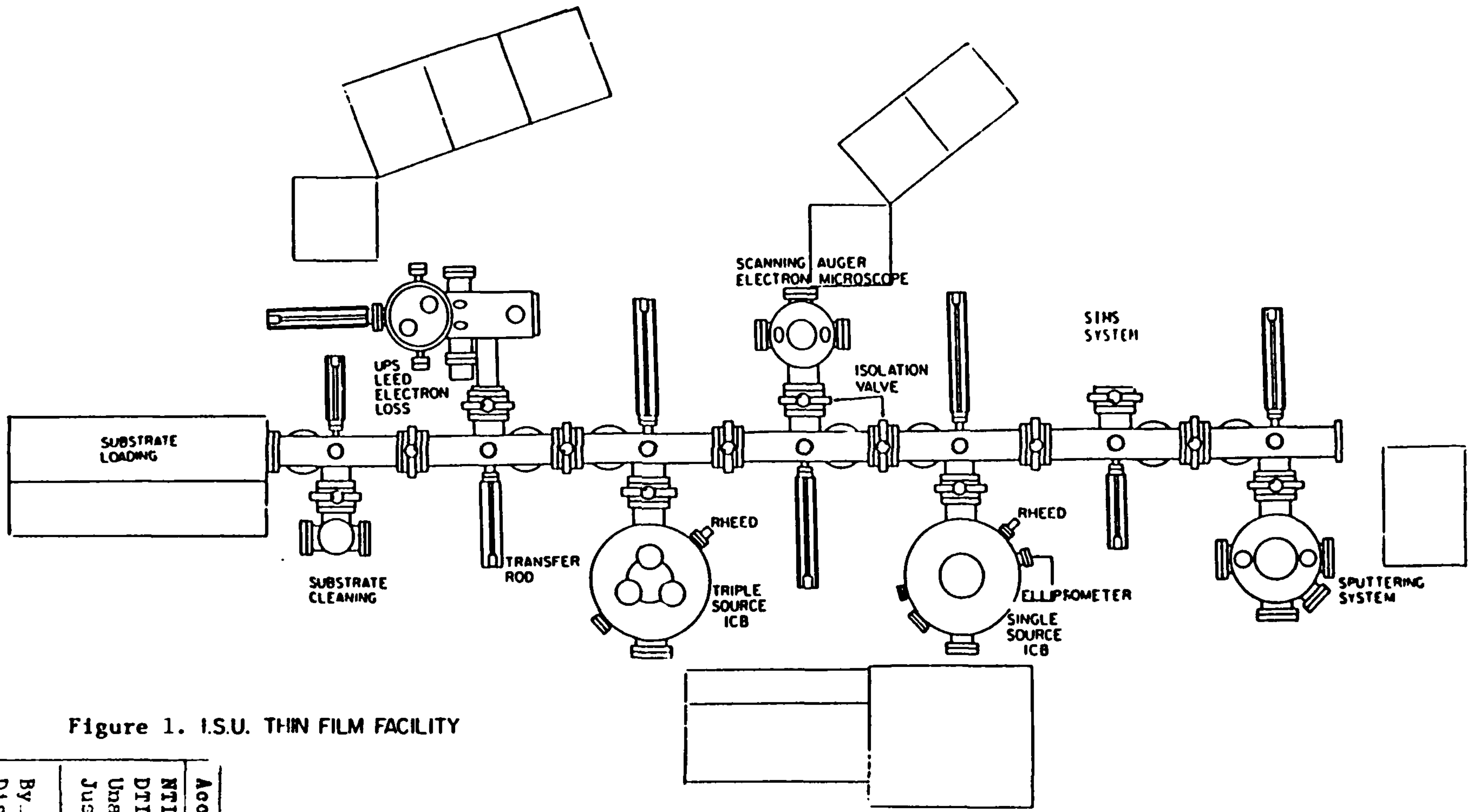

Figure 1. I.S.U. THIN FILM FACILITY

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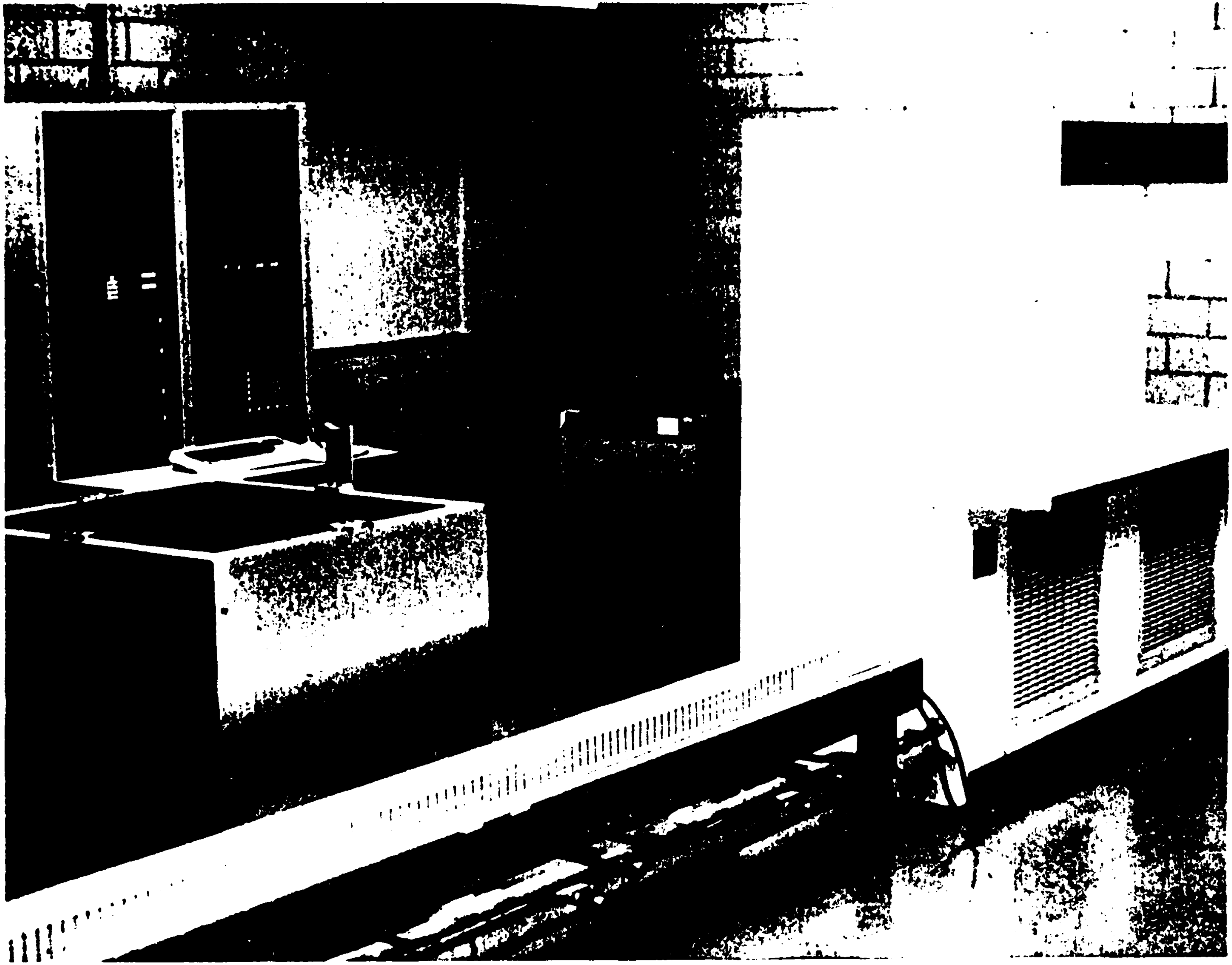

Figure 2. Service chase below transfer line in initial stages of construction.

For the single source ICB, the control system, power supplies, and the source were purchased from Eaton Corporation. The vacuum chamber was designed locally and custom fabricated. Figure 3 shows the vacuum chamber and Figure 4 shows the ICB source mounted on the base flange of the chamber. Figure 5 is an overview of the ICB system with source ready to install. The vacuum pumps for the chamber include a 2500ℓ/sec Ti sublimater (Figure 6) and a 500ℓ/sec turbomolecular pump with mechanical backing pump. Base pressure in the system is in the low 10^{-9} torr range.

The chamber has ports for RHEED and ellipsometry. A standard 10kV RHEED unit for MBE was purchased from Perkin-Elmer. This unit is used to monitor the surface structure of the growing film during deposition.

Ellipsometry is a technique just beginning to be used for monitoring thin film growth. It appears to be particularly useful for studies of island growth. A Gaertner ellipsometer with capability for obtaining a data point every 5 seconds can be attached to the ellipsometry ports on the ICB and monitor the film during deposition. For detailed studies of the initial growth stages of the film, however, a higher data rate is required. A new system with a 0.1 sec/data point capability which was designed and built locally as a M.S. thesis project is currently being tested. It will provide the detail needed for film nucleation studies.

Other diagnostics on the ICB chamber include a quartz crystal thickness monitor, a residual gas analyzer, and a Faraday cup for beam current measurements.

The transfer line, a section of which is shown in Figure 7, consists of seven sections isolated by gate valves. Each section can be individually pumped and contains a magnetically coupled push rod to move wafers from the main transfer line to the chambers. The line has a six-inch ID providing for use of three-inch diameter wafers. Ports are provided for viewing, vacuum gauging, and pumping as well as for the transfer drive mechanisms.

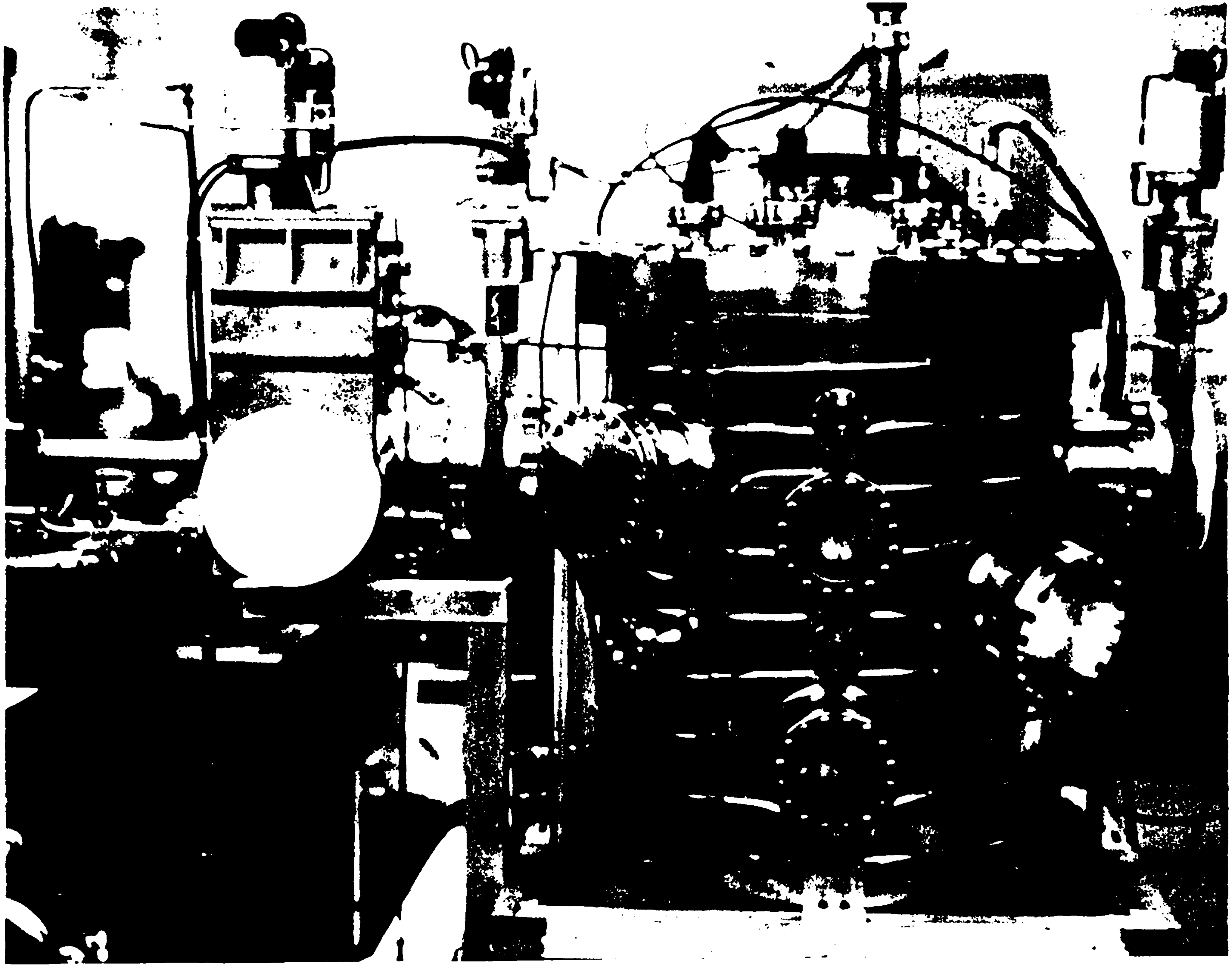

Figure 3. Ultrahigh vacuum chamber for ICB system.

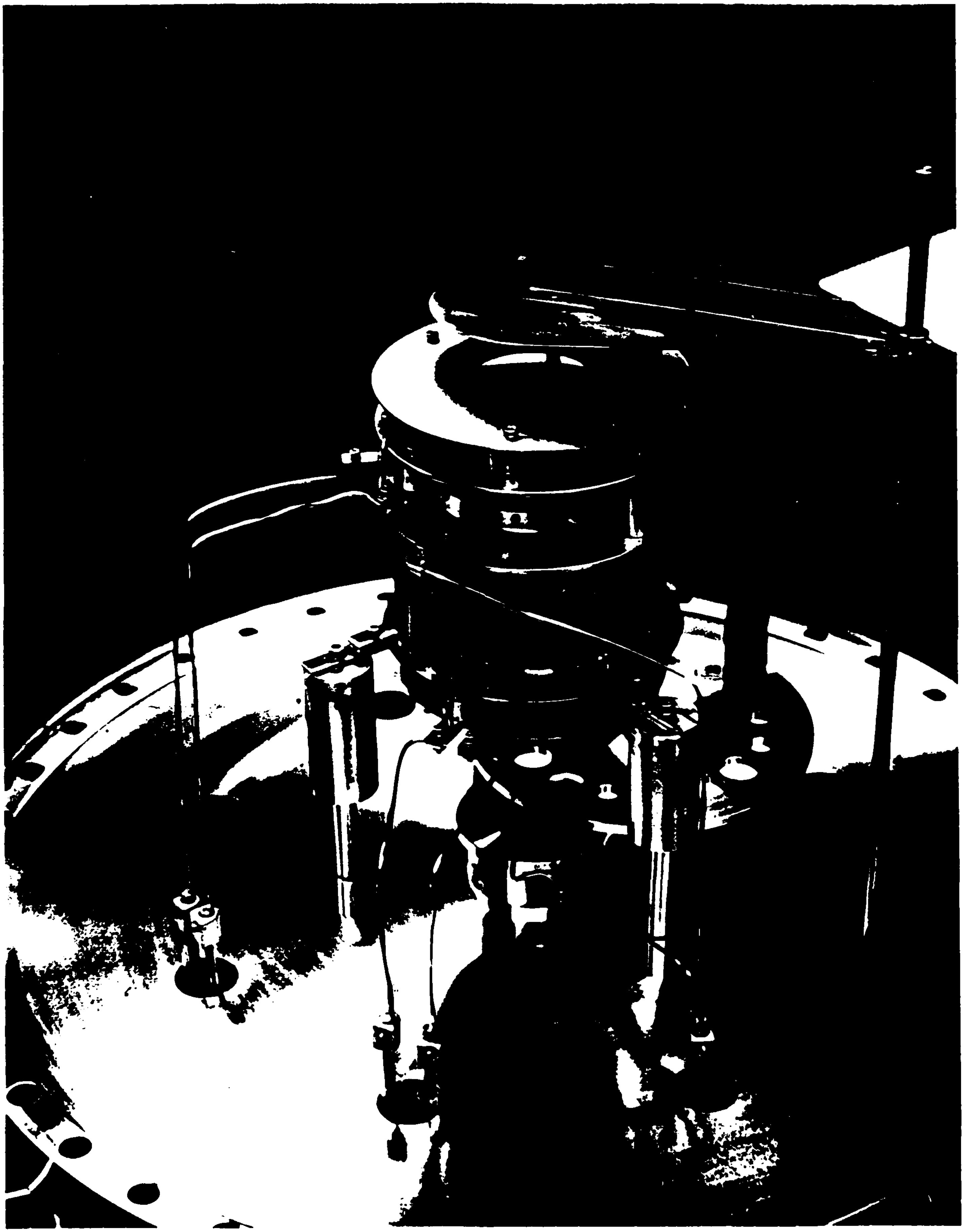

Figure [illegible]. Ionized cluster beam source mounted on [illegible] flange.

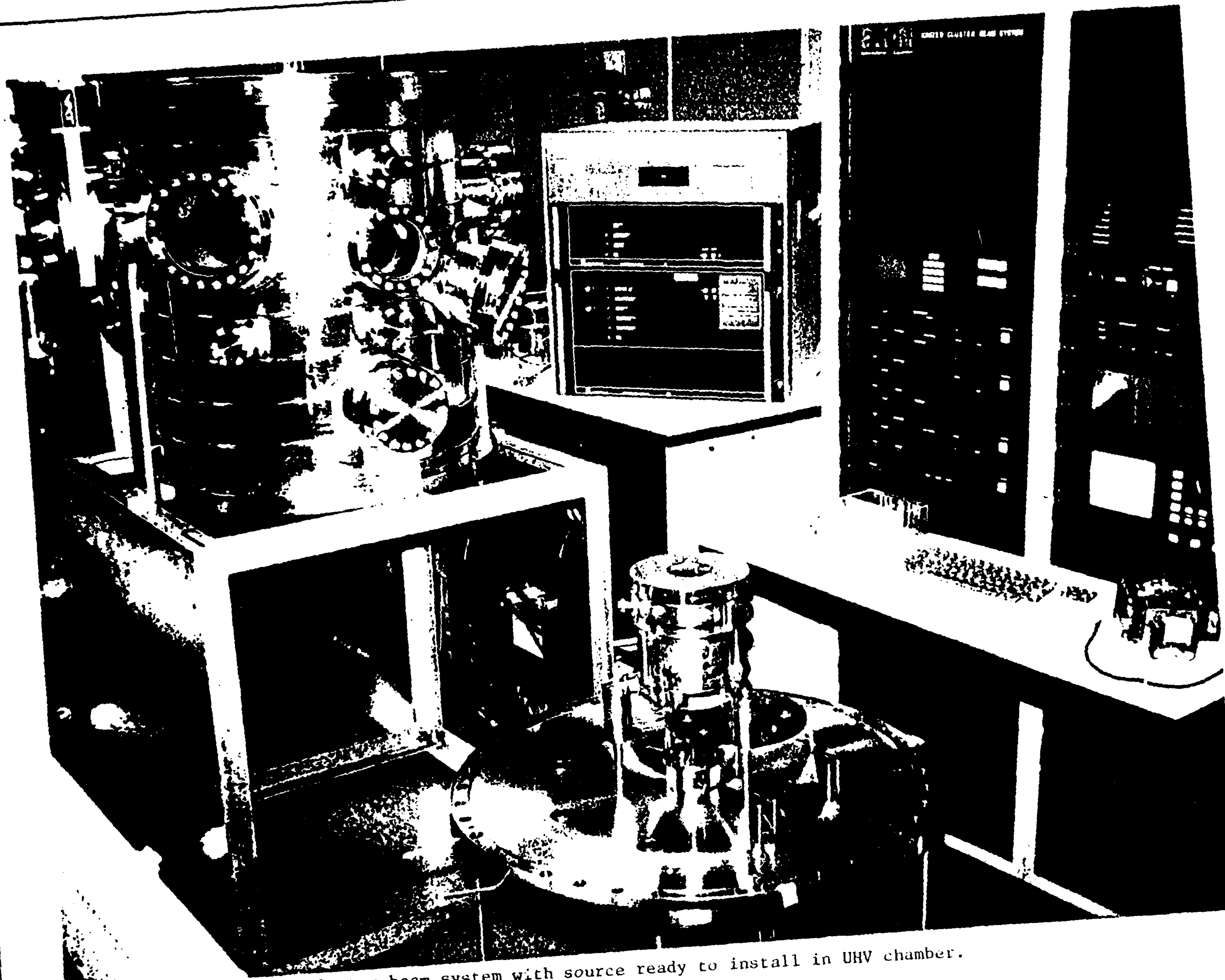

Figure 5. Ionized cluster beam system with source ready to install in UHV chamber.

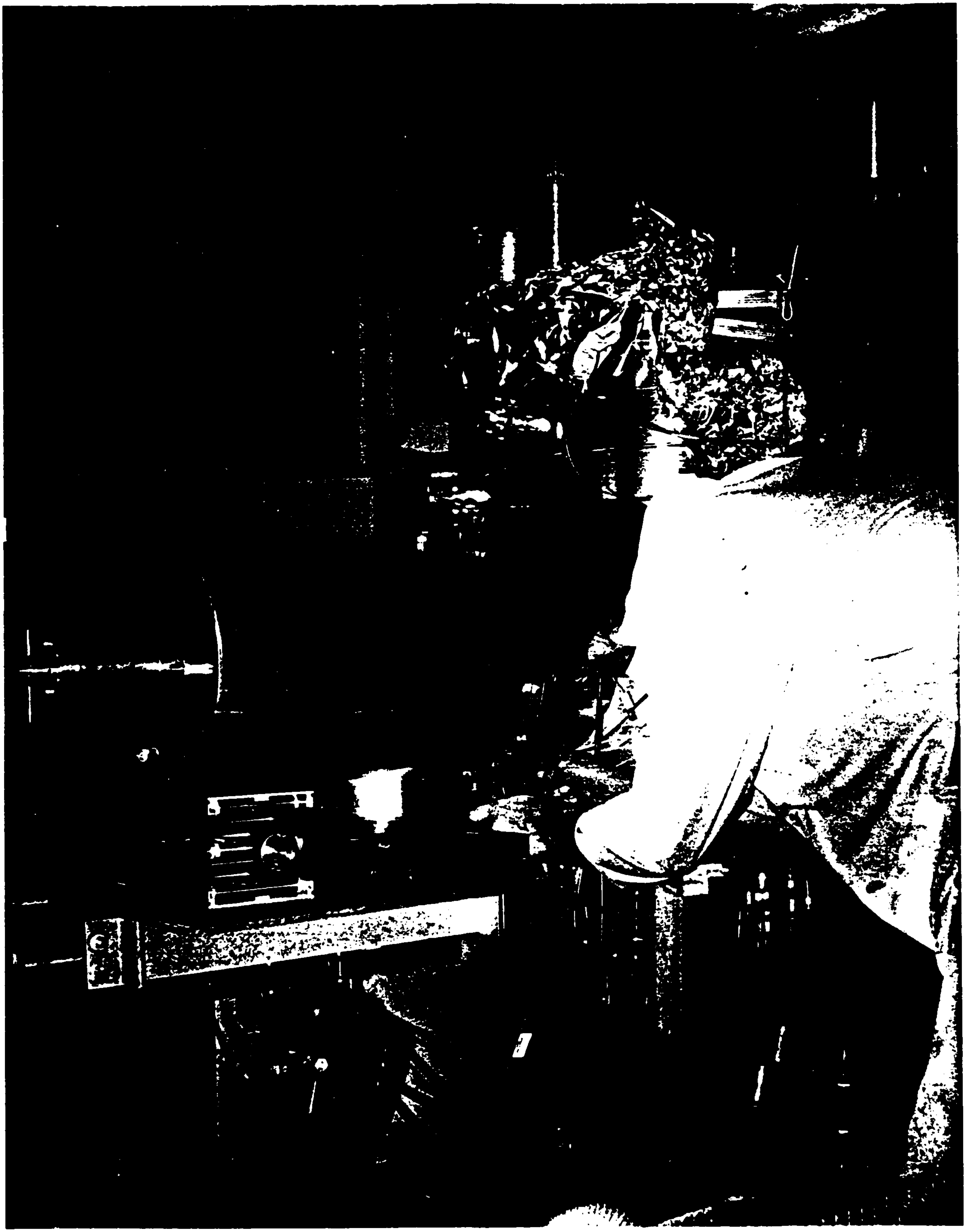

Figure 6. Ionized cluster beam system with Ti sublimation well being attached.

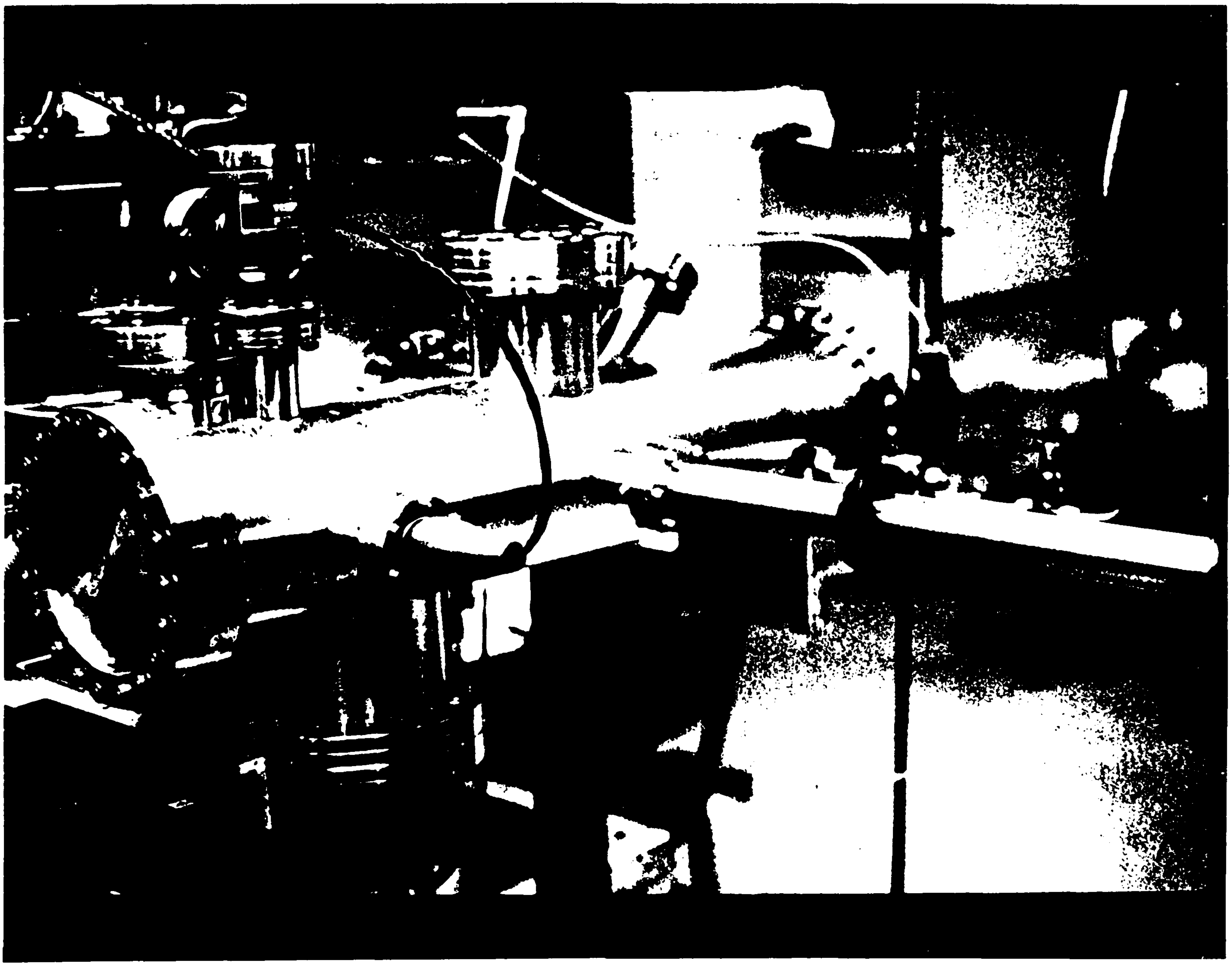

Figure 7. Section of wafer transfer line attached to the ICB chamber.

After initial bakeout and testing of the ICB system, a series of silicon depositions were attempted on silicon substrates. The upper limit on the source temperature that could be obtained was 1700°C. Vacuum at this temperature was maintained at ~2 x 10^{-8} torr. Silicon was deposited on the substrates but the crucible temperature was below the 2000-2200°C required for cluster formation. The electron bombardment crucible heater was found to be very prone to burnout and to heat the crucible in a very nonuniform manner. In addition, there was severe warpage of the radiation shields. Negotiations for a replacement source were started with Eaton Corporation.

In an effort to get work started with the ICB, experiments were redirected to the higher vapor pressure metals, aluminum and zinc. Several metallic films were deposited although the crucible heater repeatedly shorted out to the radiation shields. Several depositions of zinc were done as a function of cluster acceleration voltage. Improved adhesion of the zinc films to the silicon substrates was clearly demonstrated as the voltage was increased.

Because of our interest in piezoelectrics, we attempted to deposit AlN films by the addition of nitrogen gas to the chamber to a pressure of ~5 x 10^{-5} torr. We succeeded in incorporating nitrogen into the films but were unable to get stoichiometric compositions.

An alternate approach was tried for ZnO films. A tube was inserted into the chamber such that oxygen could be introduced directly into the ionization region of the source. This technique allowed the deposition of stoichiometric ZnO films but the presence of oxygen in the chamber further shortened the life of the filaments.

In order to gain a better understanding of the source design, the source was modelled on the computer and equal potential contour lines were plotted. Figure 8 shows the model with equal potential lines at 1000V intervals. To further clarify the system, the potential lines were also plotted every 100 volts above the source as shown in Figure 9. As can be seen from these figures, the fields in the system tend to spread the

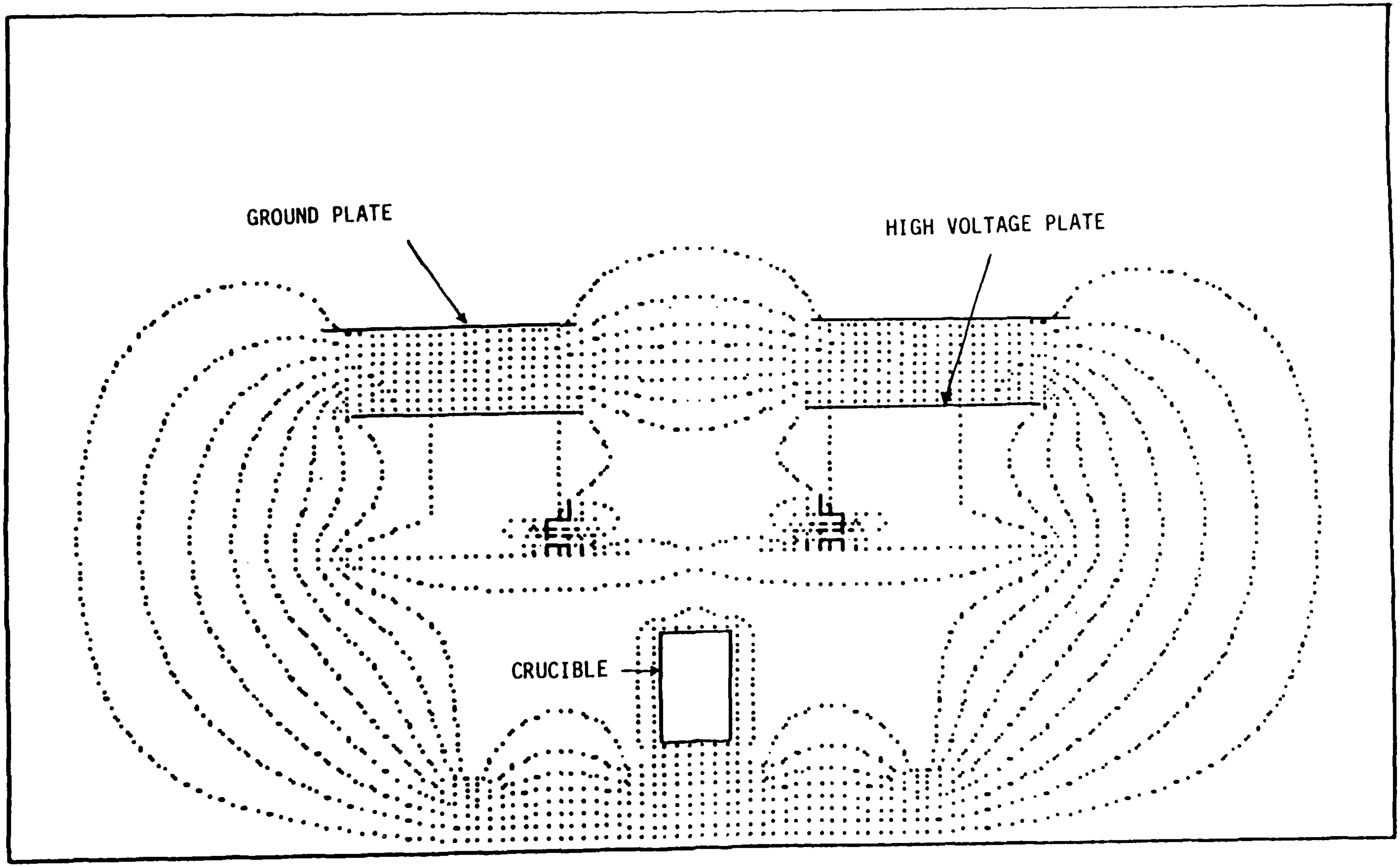

Figure 8. Equal potential lines every 1000 volts around the ICB source. Data is from a computer model of the Eaton source with 10kV accelerating voltage.

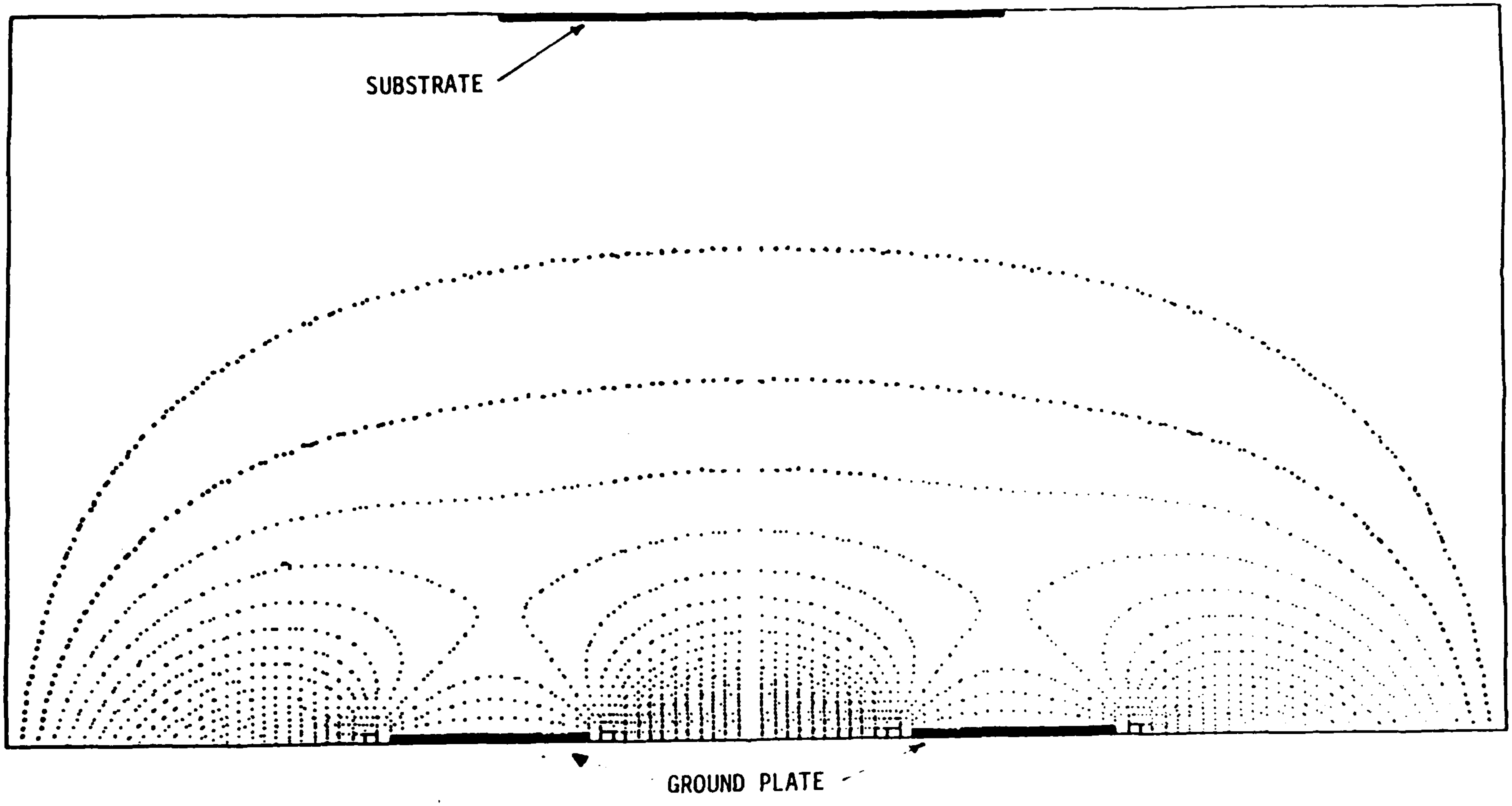

Figure 9. Equal potential lines every 100 volts from the ground plate of the source to the substrate.

charged beam which is consistent with excessive amounts of material deposited elsewhere in the system.

After considerable negotiation with Eaton Corporation, we were provided with a new style source which uses a graphite picket heater and a water cooled shroud. This new source is currently being installed.

The high vacuum sputtering system in the TFF (Figure 10) has been used to deposit Al and AlN films. A base pressure of 2×10^{-9} torr can be obtained in this system before backfilling with the sputter gas. AlN films with the desired columnar structure and which exhibit piezoelectric properties has been obtained.

The electron energy loss spectrometer shown in Figure 11 is currently being used to investigate amorphous silicon surface phonons with a 6meV resolution. This chamber with a base pressure of 5×10^{-11} torr is also used for LEED and UPS studies.

Figure 10. Sputter deposition system in thin film facility.

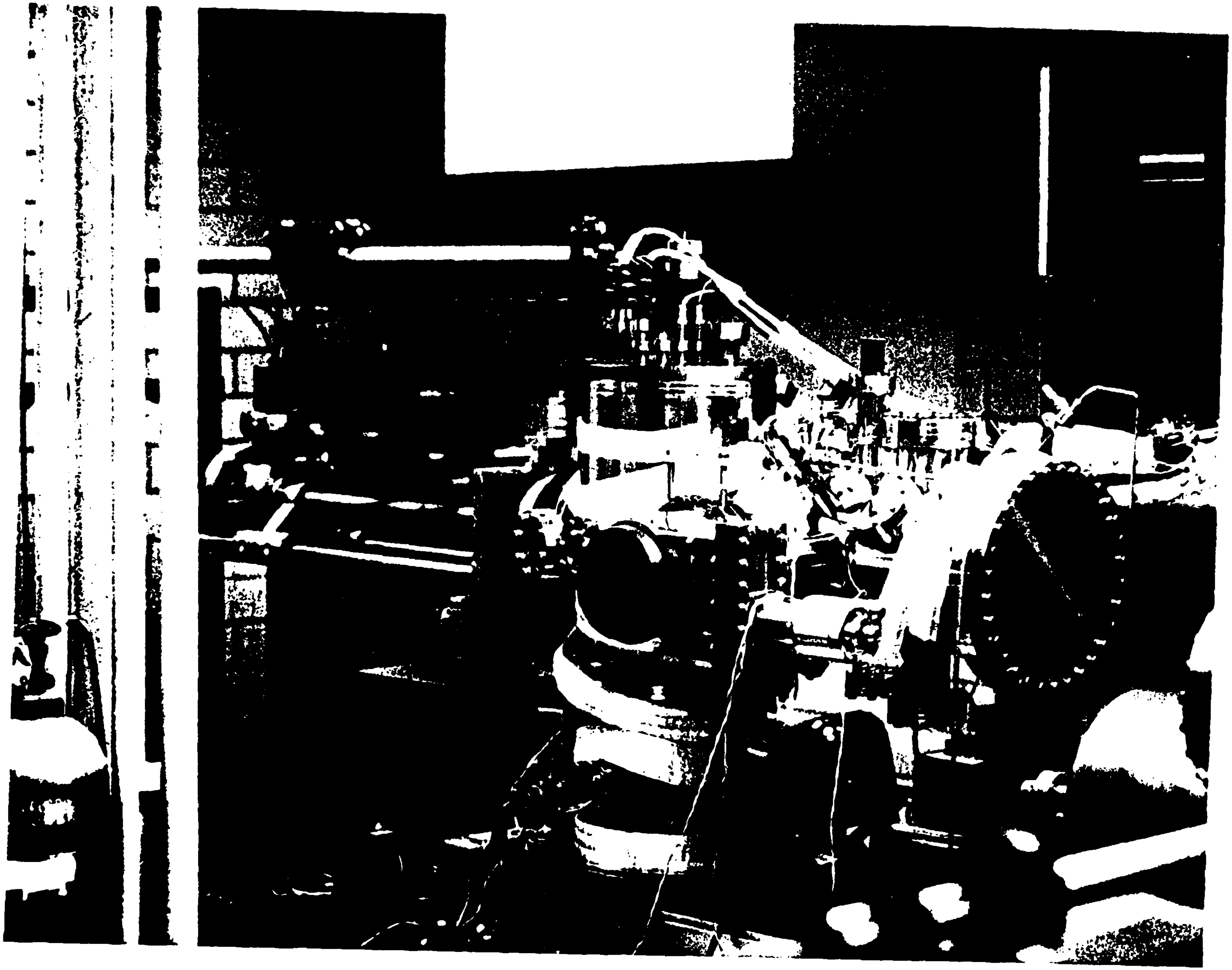

Figure 11. High resolution electron energy loss spectrometer.